

REMARKS

The non-elected claims have been cancelled without prejudice to the right to file a continuing application directed thereto.

Acknowledgement of the IDS of January 28, 2005 is respectfully requested.

An amendment to correct the partly illegible material on page 5 is presented above.

The Examiner's understanding of claims 12 and 13 was correct and a conforming amendment has been made. Accordingly, withdrawal of the rejection under 35 U.S.C. § 112 is respectfully requested.

Claims 1 – 3 have been combined and conforming changes, and correction of typographical errors, have been made in other claims. A new claim 21 has been presented and basis for this claim is found on page 22 in Examples 8-14.

In recent years, attempts have been made to reduce the size of monolithic piezoelectric parts by reducing the thickness of the layers of the ceramic sheets which make up such parts and increasing the number of ceramic sheets. However, the internal electrode materials disperse within the ceramic body, which leads to deterioration of the piezoelectric properties and poor reliability.

For monolithic piezoelectric parts such as monolithic piezoelectric actuators, audio emitters, sensors and the like, a high piezoelectric d constant is required. When the piezoelectric ceramic material is a lead perovskite type material, it has been observed that the piezoelectric d constant is conspicuously deteriorated when sintering within a low oxygen atmosphere because the low oxygen concentration promotes the generation of oxygen pores. Indeed, when the oxygen concentration is reduced to less

than 1% by volume or when a soft piezoelectric ceramic material with a high piezoelectric d constant is used, the deterioration is so severe that it is difficult to form the desired monolithic piezoelectric part. It will be appreciated that actuators, audio emitters, sensors and the like require the use of soft piezoelectric ceramic material with a high piezoelectric d constant whereas other types of piezoelectric devices such as piezoelectric transformers use a hard type piezoelectric ceramic material with a high mechanical quality coefficient. The present invention is based in part on the discovery that a layered article which has a plurality of piezoelectric ceramic layers and spaced internal electrode layers disposed in the part can be fabricated without deteriorating the piezoelectric d constant by co-sintering in an atmosphere where the oxygen concentration is at least about 5 volume % or less, but not 0%, when the molar quantity of the A site of the perovskite has been reduced by about 0.5 to 5 mole % from the stoichiometric amount and the average valance of the B site component increased to greater than 4 but less than 4.1. This is surprising and unexpected.

Claims 1-5, 7 and 14-16 have been rejected under 35 U.S.C. § 103 over Randall in view of Ponomarev and Horikawa 408.

The Randall reference relates to co-fired multilayered piezoelectric ceramic materials with base metal electrodes. It is pointed out that there are significant problems related to such co-firing, including removal of organic binder material without residual carbon, low firing temperatures, firing without oxidation, firing with copper as an electrode without formation of copper oxide, and firing without reduction of the PZT or other ceramic material. See paragraph [0007]. To overcome these problems, Randall teaches a process in which a layer of piezoelectric ceramic has applied a first layer comprising an organic material, a flux and a dopant, a layer of a base metal powder whose particles are coated with an inorganic material for passivation is applied and the layering is continued until a desired structure is

achieved, whereupon the resulting structure is heated under a partial oxygen pressure from 10^{-4} atmosphere to ambient to remove the organic material and then the multilayered structure is sintered at a partial oxygen pressure of about 10^{-3} to 10^{-10} . As the Examiner has observed, this reference does not teach or suggest using a perovskite ceramic whose A and B site molar quantities have been altered from the stoichiometric composition.

The Ponomarev reference has been cited solely to teach that low loss hard piezoelectric ceramic materials are desired in multilayered piezoelectric ceramic transformers.

Horikawa '408 relates to low loss piezoelectric ceramics for high frequency filters and isolators. The piezoelectric ceramic has a particular composition given at column 2, lines 52-55, and is formed by preparing a calcined molded body of the ceramic which is sintered and thereafter processed for application of electrodes. Co-firing a green piezoelectric ceramic (regardless of composition) with internal electrodes under any conditions is neither taught nor suggested in this reference.

The rejection in this case is predicated on substituting the Horikawa ceramic for the ceramic in Randall based on the assertion that Ponomarev teaches a low loss material would be advantageous. It is respectfully submitted, however, that this approach ignores the fact that the prior art is well aware of the fact that sintering a lead perovskite piezoelectric ceramic material in a reduced oxygen atmosphere causes significant deterioration in the piezoelectric d constant and can even render the sintered ceramic unusable for its intended purpose. Such deterioration is illustrated, for example, in the comparative examples in Table 3 of the present application. The piezoelectric ceramic of Horikawa may have a reduced lead molar quantity but it is significant that the piezoelectric is not sintered in a reduced oxygen atmosphere. It is

respectfully submitted that one skilled in the art would not sinter the Horikawa green ceramic in such a reduced oxygen atmosphere, regardless of whether or not there are internal electrodes. Accordingly, one skilled in the art would not substitute the Horikawa piezoelectric ceramic for the piezoelectric material of Randall. Even ignoring Randall's teaching about the necessity of using an organic material, flux, dopant and base metal particles coated with a material capable of protecting those particles against oxidation, Randall's process involves sintering under a reduced oxygen atmosphere together with a preliminary heating which is also possibly under a reduced oxygen atmosphere. One skilled in the art would expect the product of this hypothesized procedure to be characterized by a deteriorated piezoelectric d constant. When proceeding pursuant to the present invention, that result is avoided. Nothing in the prior art teaches or suggest such a result could be achieved.

Claims 1-5, 7-11 and 14-17 were rejected under 35 U.S.C. § 103 over Horikawa '328 in view of Ponomarev, Horikawa '408 and JP '433.

Horikawa '328 has been cited to show co-sintering of a structure having laminated green piezoelectric ceramic and internal electrodes. The Examiner has acknowledged that this reference does not disclose limiting the lead quantity or sintering in a reduced oxygen atmosphere. This reference is, accordingly, less relevant than the Randall reference employed in the prior rejection.

The Ponomarev and Horikawa '408 references have been discussed above. The Japanese reference teaches a hard piezoelectric ceramic having silver electrodes where the diffusion of silver into the ceramic is reduced by sintering at an oxygen density of 1-10%.

This combination of references suffers from the same deficiencies as the prior rejection. More particularly, the hypothesized combination would not be made since it is well known that sintering a lead perovskite piezoelectric ceramic under low oxygen conditions would result in a deterioration of the piezoelectric d constant when a high piezoelectric d constant is desired for the intended application. The oxygen density suggested in the Japanese patent may address the problem of diffusion of silver into the ceramic but the d constant would still be greatly deteriorated. Accordingly, those skilled in the art would not make the combination hypothesized and would not realize the present invention.

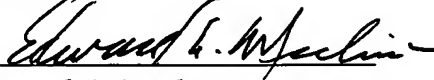
Claim 6 was rejected under 35 U.S.C. § 103 based on the references applied to claim 4, i.e., both of the previously discussed rejections, in further view of Feltz. Feltz has been cited to show the composition of the B position but not to otherwise overcome the deficiencies in the base combination of references. Accordingly, the further combination of those references with Feltz cannot render the invention obvious.

Claims 12 and 13 were rejected under 35 U.S.C. § 103 over the references applied to claim 11 in further combination with JP '035. This additional reference has been cited only with regard to the internal electrodes and therefore does not serve to render the claimed invention any more obvious than it would under the base combination of references. Withdrawal of this rejection is also respectfully solicited.

In view of the above amendment, applicant believes the pending application is in condition for allowance.

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Respectfully submitted,

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